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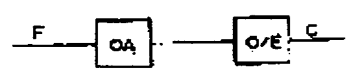
(54) OPTICAL TRANSMITTER

(57)Abstract:
PURPOSE: To obtain constitution wherein the loss of a dispersed medium causes no deterioration in reception sensitivity while adding the dispersed medium which compensates the dispersion of a transmission line.
CONSTITUTION: A receiver consisting of an optical amplifier OA and an O/E conversion part has its S/N as a receiver determined by an initial-stage optical amplifier OA and has higher sensitivity than reception by only the O/E. Further the level itself of an optical signal after optical amplification is not S/N- sensitive. For the purpose, the output level of the OA is set much higher than the reception sensitivity of the 0/E and then even when the dispersed medium is interposed between the OA and OE, the dispersion can be compensated without any influence upon the reception sensitivity.



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[Claims]

[Claim 1] An optical transmitter comprising a dispersive medium for compensating a dispersion characteristic in a transmission line between an optical amplifier and an optical electrical converting section, or between an optical amplifier and an optical amplifier, in an optical receiving circuit, an optical transmission circuit or an optical repeater, which has one or a plurality of optical amplifiers.

[Detailed Description of the Invention]

[0001]

[Industrial Applicability]

The present invention relates to an optical transmitter, which is required in a high-speed optical transmission system and a long distance relay transmission system.

[0002]

[Prior Art] Waveform distortion due to dispersion in optical fiber as the transmission line and spectral spread of signal light, which is transmitted therethrough, was a significant problem for achieving high-speed and long distance relay digital optical transmission system. As a solving method of the above problem, the most effective method

is to reduce the dispersion in the fiber to zero. However, in a given fiber, the dispersion of the fiber becomes zero only at a specific wavelength (zero-dispersion wavelength); the plus/minus sign of the dispersion is inverted in either side of the zero-dispersion wavelength; and the dispersion becomes larger as the wavelength is away from the zero-dispersion wavelength. When taking an actual system from the view point of the variation of the wavelength characteristic in a fiber and a light source, even in a system which utilizes the zero-dispersion wavelength of the fiber, the wavelength of the light source and the zero-dispersion wavelength of a used fiber do not perfectly agree with each other. Accordingly, a finite dispersion σ is included in the wavelength. Therefore, as shown in Fig. 4, a dispersive medium (for example, a fiber), which has the just opposite dispersion ($-\sigma$) with respect to the dispersion of the fiber as the transmission line, is connected to reduce the total dispersion to zero. Thereby, after removing the degradation in the waveform due to the dispersion, the signal light can be converted into electrical signal by a light receiving element.

[0003]

[Problems to be Solved by the Invention] In

the above-described prior art, there resides the following problem. Generally, since a direct detection system, which converts the intensity of the optical signal into electrical signal, is simple and provides satisfactory characteristics, the direct detection system is widely employed as a practical device. However, in the direct detection system, the S/N-ratio of the demodulated electrical signal is determined depending on the noise characteristic of an O/E converting section and the power of input optical signal. Accordingly, when a dispersive medium is added, the medium causes to reduce the reception sensitivity by a level equivalent to the loss thereby. The above problem is the same for the transmission side. That is, the dispersive medium reduces the transmitting output by a level equivalent to the loss thereby. Accordingly, allowable loss, which is allotted to the transmission line as difference in transmission/reception level, is reduced. That is, in order to compensate the degradation in the waveform due to the dispersion, the reduction of the difference in transmission/reception level occurs simultaneously. Therefore, the direct detection system is not always a practical and effective method.

[0004]

The present invention has been achieved to solve the above mentioned problem. An object of the invention is to provide an optical transmitter, which enables such configuration that dispersive medium for compensating dispersion in the transmission line is added, but the loss by the dispersive medium causes no degradation in the reception sensitivity.

[0005]

[Means for Solving the Problems]

The present invention is characterized in that an optical transmitter comprises a dispersive medium for compensating a dispersion characteristic in a transmission line between an optical amplifier and an optical electrical converting section, or between an optical amplifier and an optical amplifier, in an optical receiving circuit, an optical transmission circuit or an optical repeater, which has one or a plurality of optical amplifiers.

[0006]

[Operation]

According to the present invention, it is possible to compensate the dispersion in the transmission line without lowering the performance of a transmitter caused by the loss of the dispersive medium due to suitable combination between an optical amplifier and a dispersive medium for a device.

[0007]

[Embodiments of the Invention]

Now, referring to the drawings, a first, second, third and fourth embodiments according to the present invention will be described below. In the present invention, it is possible to compensate the dispersion in the transmission line without lowering the performance of a transmitter caused by the loss of the dispersive medium due to suitable combination between an optical amplifier and a dispersive medium for a device. That is, in the direct detection system, the S/N is determined by an optical electrical converting section, and is converted into base-band electrical signal. Therefore, after the optical/electrical conversion, the influence of the dispersion in the transmission line cannot be equalized. Accordingly, the dispersion medium has to be interposed in front of a circuit, which determines the S/N. Accordingly, the loss by the dispersion medium is sensitively reflected on the reduction of the difference in transmission/reception level. In order to solve the above problem, in a receiver in accordance with the present invention shown in Fig. 5, which comprises an optical amplifier OA and an O/E converting section, the S/N as the receiver is determined by the optical amplifier OA in the first step; and the S/N is higher

in sensitivity than the case of reception with the O/E only. Further, after the optical amplification, the level itself of the optical signal is not S/N-sensitive. Accordingly, by setting the output level of the OA to a level satisfactorily higher than the reception sensitivity of the O/E, it is possible to obtain such configuration that, even when the dispersive medium is interposed between the OA and the OE, compensates the dispersion without giving any influence on the reception sensitivity.

[0008]

First embodiment. Fig. 1 shows a case where an optical receiving section is configured upon employing the above-described principle. A symbol "C" denotes a coaxial cable; "O/E" denotes an optical/electrical conversion circuit; "D" denotes a dispersive medium; "OA1" and "OA2" denote an optical amplifier, respectively; and "F" denotes an optical fiber. In the case where the loss of the dispersive medium is large, the OA2 is necessary.

[0009]

Second embodiment. Fig. 2 shows an embodiment in the case where an optical amplifier is employed as an optical repeater. The dispersion in the transmission line is made to compensate upon interposing a dispersive medium, which gives the

dispersion of a fiber in a transmission line to an inverted dispersion previously, between two optical amplifiers. In Fig. 2, "F1" and "F2" denote an optical fiber respectively; "D" denotes a dispersive medium; and "OA1" and "OA2" denote an optical amplifier respectively. By an optical amplifier OA1 in a first step, after amplifying an optical signal, which is attenuated in the transmission line, the dispersion in the transmission line can be compensated without allowing the output characteristics of the optical signal to be degraded by using the same principle and configuration as that of the first embodiment. In the case of this device, the S/N is determined by the OA1, which amplifies the arrived optical signal first. Accordingly, a downstream dispersive medium compensates the dispersion without causing any degradation in the S/N-ratio. When the optical output of the optical amplifier in the first step is satisfactorily high, or when the loss of the dispersive medium is negligible, the OA2 may be omitted.

[0010]

Third embodiment. Fig. 3 shows an embodiment in a transmitting section. The transmitting section comprises a dispersive medium, which previously gives an inverted dispersion to the transmission line fiber

dispersion, and an optical amplifier, which compensates the optical loss caused by the dispersive medium. In Fig. 3, "C" denotes a coaxial cable; "E/O" denotes an electrical/optical conversion circuit; "D" denotes a dispersive medium; "OA" denotes an optical amplifier; and "F" denotes an optical fiber. In a configuration such that the E/O output from an electrical/optical converting section is directly input to an optical amplifier OA without using any dispersive medium D, when an Er-doped optical fiber amplifier is used as the optical amplifier OA, the optical output power PO from the electrical/optical conversion section E/O is amplified by an level equivalent to the gain of the optical amplifier OA. However, even when the optical output power PO is increased exceeding the input power Pin of the optical amplifier OA, which is larger than the saturation output of 3dB of the optical amplifier OA, since the output from the optical amplifier OA is saturated, the optical output power is increased little. By interposing a dispersive medium D between the electrical/optical conversion section E/O and the optical amplifier OA as shown in Fig. 3, not only that the loss caused by the dispersive medium D is compensated by the optical amplifier OA, but also the optical output power PO is further amplified.

Particularly, under the condition that saturation has occurred, the loss caused by the dispersive medium D gives no influence on the output power from the optical amplifier OA, because loss caused by the dispersive medium D is equal to or more than the reduced relative to the unsaturated gain in the optical amplifier. For example, in the case where a gain compression of 10dB is generated by the saturation in the optical amplifier OA, when the loss caused by the dispersive medium D is 10dB or less, the optical output power from the transmitting section is the same as the case where the dispersive medium D is not interposed therebetween. Accordingly, the output performance is not degraded by the loss caused by the dispersive medium D.

[0011]

Fourth embodiment. Fig. 4 is an embodiment of the case where an optical fiber is specifically used as the dispersive medium. This is an example in which a fiber amplifier doped with a rare earth ion (erbium) is used as the optical amplifier. This is a configuration such that a wavelength dispersion in a dispersion shift fiber of 150km (F1), which is used as the transmission line, is eliminated by a dispersive medium, which is interposed between the optical amplifier (OA) and the optical electrical conversion (O/E) (optical fiber F2; which has an

inverted sign of the wavelength dispersion and a larger value with respect to F1). That is, as shown in Fig. 7 and Fig. 8, the effect of the dispersion compensation can be experimentally verified.

[0012]

[Effects of the Invention]

As described above, according to the present invention, in the optical transmitting section, in the optical repeater section or in the optical receiving section, it is possible to compensate the dispersion of the fiber in each transmission line without allowing the characteristics to be degraded caused by the loss of the dispersive medium for compensation. Accordingly, the optical signal with a waveform distortion can be obtained after a long distance transmission.

[Brief Description of the Drawings]

Fig. 1 is a diagram showing a configuration of a first embodiment of the present invention.

Fig. 2 is a diagram showing a configuration of a second embodiment of the present invention.

Fig. 3 is a diagram showing a configuration of a third embodiment of the present invention.

Fig. 4 is a diagram showing a conventional configuration.

Fig. 5 is a diagram showing an example of a

configuration of a receiving circuit in which the optical amplifier of the present invention is employed.

Fig. 6 is a diagram showing a configuration of a fourth embodiment of the present invention.

Fig. 7 is a diagram showing a waveform after 150Km transmission without dispersive medium according to the fourth embodiment of the present invention.

Fig. 8 is a diagram showing a waveform after 150Km transmission with dispersive medium according to the fourth embodiment of the present invention.

[FIG. 6]

(1) ZERO-DISPERSION OPTICAL FIBER F1

(2) OPTICAL AMPLIFIER OA

(3) OPTICAL/ELECTRICAL CONVERSION O/E

(4) OPTICAL FIBER F2 (DISPERSIVE MEDIUM)

(5) OPTICAL TRANSMITTER (RECEIVER)

[FIG. 7]

(1) WAVEFORM AFTER 150KM TRANSMISSION

(2) WITHOUT DISPERSIVE MEDIUM

[FIG. 8]

(1) WAVEFORM AFTER 150KM TRANSMISSION

(2) WITH DISPERSIVE MEDIUM

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審査請求　未請求　請求項の数１（全　４　頁）

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特許法第30条第１項適用申請有り　1990年８月６日　日本電信電話株式会社発行の講演論文「光増幅と等化機能をもつ低雑音広帯域受信器を使った17Ｇｂ／ｓ長距離ファイバ伝送実験（講演ＮＯ　ＴｕＡ２）」に発表

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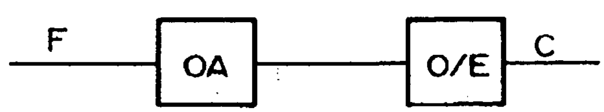
(54)【発明の名称】　光伝送装置

(57)【要約】

【目的】　伝送路の分散を補償する分散媒質を付加しながら、分散媒質の損失が受信感度の劣化を招かない構成を可能とする。

【構成】　光増幅器ＯＡとＯ／Ｅ変換部とからなる受信装置は、初段の光増幅器ＯＡで受信機としてのＳ／Ｎが決定され更にＯ／Ｅ単独で受信するよりも高感度になる。しかも、光増幅された後では、光信号のレベルそのものは、Ｓ／Ｎ敏感でない。そこで、ＯＡの出力レベルがＯ／Ｅの受信感度より十分高く設定することにより、ＯＡとＯＥの間に分散媒質を挿入しても受信感度には影響せず分散を補償できる構成が可能となる。



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【特許請求の範囲】

【請求項1】　1台又は複数の光増幅器を有する光受信回路、光送信回路あるいは光中継器において、光増幅器と光電気変換部あるいは光増幅器と光増幅器との間に、伝送路の分散特性を補償する分散性媒質を有することを特徴とする光伝送装置。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は、高速光伝送システム、長中継伝送システムにおいて必要とされる光伝送装置に関する。

【0002】

【従来の技術】高速・長中継デジタル光伝送システムを実現する上で、伝送路である光ファイバの分散と伝送される信号光のスペクトル広がりによる波形歪みが大きな問題であった。それを解決する方法として、ファイバの分散を零にするのが最も有効な方法である。しかし、あるファイバが与えられたときそのファイバの分散は、ある特定の波長（零分散波長）で零となるのみで、零分散波長の両側で分散の符号が反転し、零分散波長からずれる従って大きくなって行く。現実のシステムを考えた場合、ファイバおよび光源の波長特性のバラツキを考えたとき、例えファイバの零分散波長を用いたシステムでも、光源の波長と施設されるファイバの零分散波長は完全には一致せず有限の分散σを持つことになる。そこで、図4のように伝送路であるファイバの分散とちょうど反対の分散（$-\sigma$）を持った分散媒質（例えばファイバ）を接続しトータルの分散を零にすることにより、分散による波形劣化を除去した後に受光素子で電気信号に変換することができる。

【0003】

【発明が解決しようとする課題】ところで、上記従来技術においては次のような問題があった。一般に、光信号の強度を電気信号に変換する直接検波方式は簡便でかつ特性も優れているため実用装置として広く用いられている。しかし、直接検波方式において復調される電気信号のS／N比はO／E変換部の雑音特性と入力光信号パワーで決定されるため、分散媒質を付加するとその媒質が有する損失分だけ受信感度の低下をもたらす。このことは送信側についても同様なことが言える。即ち、送信出力が分散媒質の損失分だけ減少し、送信受信レベル差として伝送路に割り振れる許容損失が減少する。つまり、分散による波形劣化を補償するために送受信レベル差の減少が同時に生じるため現実的な有効な方法とは言えなかった。

【0004】本発明は前記課題を解決するもので、伝送路の分散を補償する分散媒質を付加しながら、分散媒質の損失が受信感度の劣化を招かない構成を可能にした光伝送装置の提供を目的とする。

【0005】

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【課題を解決するための手段】本発明は、1台又は複数の光増幅器を有する光受信回路、光送信回路あるいは光中継器において、光増幅器と光電気変換部あるいは光増幅器と光増幅器との間に、伝送路の分散特性を補償する分散性媒質を有することを特徴とする。

【0006】

【作用】本発明によれば、光増幅器と分散媒質を装置に適した組み合せにより、伝送装置の性能が分散媒質の損失により低下することなく、伝送路の分散を補償することができる。

【0007】

【実施例】以下、本発明による第1、第2、第3、第4実施例を図面に基づき説明する。本発明においては、光増幅器と分散媒質を装置に適した組み合せにより、伝送装置の性能が分散媒質の損失により低下することなく、伝送路の分散を補償することができる。即ち、直接検波方式では、光電気変換部でS／Nが決定され、かつベースバンド電気信号に変換されてしまうため伝送路の分散の影響を光電気変換後では等化できない。従って、S／Nを決定する回路の前に分散媒質を挿入するしかないために、その損失に敏感に送受信レベル差の減少に反映されてしまっていた。かかる不具合を解決すべく本発明の図5の光増幅器OAとO／E変換部とからなる受信装置は、初段の光増幅器OAで受信機としてのS／Nが決定され更にO／E単独で受信するよりも高感度になる。しかも、光増幅された後では、光信号のレベルそのものは、S／N敏感でない。そこで、OAの出力レベルがO／Eの受信感度より十分高く設定することにより、OAとOEの間に分散媒質を挿入しても受信感度には影響せず分散を補償できる構成が可能となる。

【0008】第1実施例。図1は、上記原理を用いて光受信部を構成した場合である。Cは同軸ケーブル、O／Eは光・電気変換回路、Dは分散媒質、OA1およびOA2は光増幅器、Fは光ファイバである。OA2は分散媒質の損失が大きい場合に必要となる。

【0009】第2実施例。図2は、光中継器として光増幅器を用いた場合の実施例である。2台の光増幅器の間に、伝送路のファイバの分散に対し予め逆の分散を与える分散媒質を挿入することにより伝送路の分散を補償する。図2において、F1及びF2は光ファイバ、Dは分散媒質、OA1及びOA2は光増幅器である。第一段の光増幅器OA1により伝送路で減衰した光信号を増幅した後、第1実施例と同様の原理・構成で光信号の出力特性を損なうことなく、伝送路の分散を補償できる。該装置の場合、到達した光信号を最初に増幅するOA1でS／Nが決定されるので、その後段分散媒質はS／N比劣化を来たすことなく分散を補償することができる。ただし、第一段の光増幅器の光出力が十分に高い場合あるいは分散媒質の損失が無視できる場合、OA2は省略することができる。

【００１０】第３実施例。図３は、送信部での実施例である。送信部において、伝送路のファイバの分散に対し予め逆の分散を与え分散媒質とそれによる光損失を補う光増幅器により構成されている。図３において、Ｃは同軸ケーブル、Ｅ／Ｏは電気・光変換回路、Ｄは分散媒質、ＯＡは光増幅器、Ｆは光ファイバである。分散媒質Ｄを用いないで直接光増幅器ＯＡに電気光変換部Ｅ／Ｏ出力を入力する構成において、光増幅器ＯＡとしてＥｒードープ光ファイバ増幅器を用いた場合、電気光変換部Ｅ／Ｏの光出力パワーＰ０は光増幅器ＯＡの利得分だけ増幅されるが、光増幅器ＯＡの３ｄＢ飽和出力以上となる光増幅器ＯＡの入力パワーＰｉｎより増加させても、光増幅器ＯＡが出力飽和し光出力パワーはほとんど増加しない。図３のように分散媒質Ｄを電気光変換部Ｅ／Ｏと光増幅器ＯＡの間に挿入することにより、分散媒質Ｄの損失を光増幅器ＯＡで補償できるだけでなく、更に増幅できる。とりわけ、飽和が生じているような条件下では、光増幅器ＯＡの未飽和利得に対し減じた分だけ、分散媒質Ｄの損失は全く光増幅器ＯＡの出力パワーに影響しない。例えば、光増幅器ＯＡの飽和により１０ｄＢ利得圧縮が生じた場合、分散媒質Ｄの損失が１０ｄＢ以下であれば、この送信部光出力パワーは分散媒質Ｄを挿入しないものと同等となり、分散媒質Ｄによる損失によって出力性能が劣化しない。

【００１１】第４実施例。図４は、具体的に分散媒質として光ファイバを用いた場合の実施例である。光増幅器として希土類イオン（エルビウム）を添加したファイバ増幅器を用いた例である。伝送路として用いた分散シフトファイバ１５０ｋｍ（Ｆ１）での波長分散を光増幅器（ＯＡ）と光電気変換（Ｏ／Ｅ）の間に挿入した分散媒質（光ファイバＦ２；ただしＦ１とは波長分散の符号が反対でその値も大きい）で打ち消す構成である。即ち、図７・図８に示す如く、実験により分散補償の効果を確認することができた。

【００１２】

【発明の効果】以上説明したように本発明によれば、光送信部で、あるいは光中継部で、あるいは光受信部で補償用の分散媒質の損失に特性を損なわれることなく、それぞれ伝送路のファイバの分散を補償することができ、長距離伝送後にも波形歪みの光信号を得ることができる。

【図面の簡単な説明】

【図１】本発明の第１実施例の構成を示す図である。

【図２】本発明の第２実施例の構成を示す図である。

【図３】本発明の第３実施例の構成を示す図である。

【図４】従来の構成を示す図である。

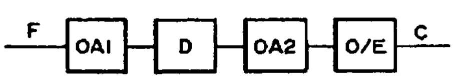
【図５】本発明の光増幅器を用いた受信回路の構成例を示す図である。

【図６】本発明の第４実施例の構成を示す図である。

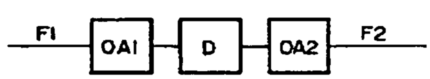
【図７】本発明の第４実施例の分散媒質なしの時の１５０Ｋm伝送後の波形図である。

【図８】本発明の第４実施例の分散媒質ありの時の１５０Ｋm伝送後の波形図である。

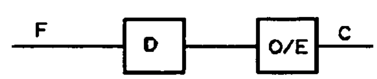
【図１】



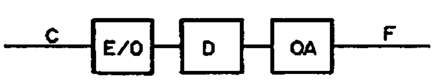
【図２】



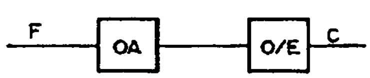
【図４】



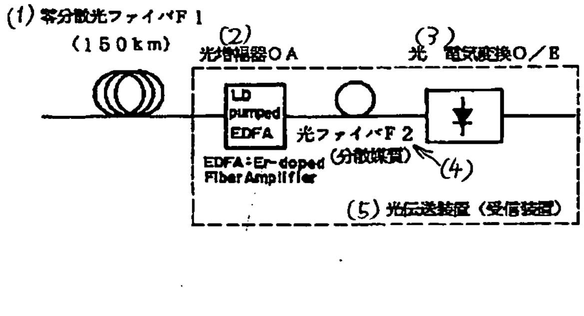
【図３】



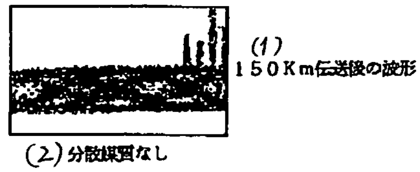
【図５】



【図６】



【図７】



【図8】